Weak Associations between Hospital Mortality Rates for Individual Diagnoses: Implications for Profiling Hospital Quality

Gary E. Rosenthal, MD

ABSTRACT

Objectives. This study examined the consistency of hospital mortality rates across different diagnoses.

Methods. Standardized mortality ratios for patients discharged in 1991 from US hospitals were determined via the Medicare Hospital Information Report.

Results. Correlations between standardized mortality ratios for different diagnoses were relatively weak, ranging from .03 to .34. Agreement between hospital rankings (based on standardized mortality ratios), as measured by the weighted kappa statistic, was also weak.

Conclusions. The present results indicate that hospital mortality rates for individual diagnoses are weakly associated. Thus, it may not be valid to generalize conclusions about hospital performance from a single diagnosis. (*Am J Public Health.* 1997;87:429–433)

Introduction

Standardized mortality data are widely used to measure hospital quality and are often used by purchasers (i.e., employers, insurers) to select hospitals.[1–17] However, because the costs of collecting and analyzing mortality data are substantial, data are generally reported only for selected diagnoses.[1,2,18,19] Although prior research has examined the validity of mortality data as a measure of hospital quality,[20–31] few studies have examined the consistency of standardized hospital mortality rates across different diagnoses.[8]

The objective of the current study was to compare standardized hospital mortality rates for several common diagnoses. The study used data reported by the Health Care Financing Administration (HCFA). Although the HCFA reports have been criticized for not adequately adjusting for severity of illness,[22,32,33] the reports include data for all hospitals and are often used by purchasers.[17] In addition, several commercial systems that are widely used to compare hospital mortality rates have similar predictive validity.[34–36] Moreover, rankings of hospital performance based on the HCFA reports may be similar to rankings determined through more precise methods of adjusting for severity of illness.[37]

Methods

Data

The study used data from the 1993 Medicare Hospital Information Report, which included information for Medicare beneficiaries discharged in fiscal year 1991 from 5505 acute care hospitals in the United States.[38] Seven diagnoses that are associated with appreciable mortality rates and that have been the subject of previous analysis[1,2,9,20,39,40] were selected for inclusion: acute myocardial infarction, congestive heart failure, pneumonia and influenza, chronic obstructive lung disease, stroke, hip fracture, and coronary artery bypass surgery. For each diagnosis, the number of patients, the observed (i.e., actual) mortality rate within 30 days of admission, and the predicted mortality rate were obtained. Predicted mortality rates were determined from multivariable models developed by HCFA and were based on age, gender, prior hospitalizations, reason for admission (based on the primary *International Classification of Diseases* [9th edition] *Clinical Modification* [ICD-9-CM] diagnosis code), and the presence of specific comorbid illnesses (e.g., cancer, diabetes) identified by ICD-9-CM codes.[38]

For each diagnosis, hospital standardized mortality ratios were determined by dividing a hospital's observed mortality rate by its predicted rate. The standardized mortality ratio is a commonly used measure of hospital performance[5]; ratios less than 1.0 denote better than expected performance, while ratios greater than 1.0 denote worse than expected performance. In addition, hospitals were categorized into quintiles, for each diagnosis, on the basis of standardized mortality ratios. As a means of decreasing variability in hospital standardized mortality ratios resulting from small sample sizes, hospitals with fewer than 100 patients for a particular diagnosis were excluded from analysis. The number of hospitals that met this threshold for each of the seven diagnoses is shown in Table 1.

Analysis

The analysis involved three principal steps. First, correlations between hospital standardized mortality ratios for each of the 21 possible pairs of diagnoses were determined by means of the Pearson

The author is with the Department of Medicine, Cleveland Veterans Affairs Medical Center, and Case Western Reserve University School of Medicine, Cleveland, Ohio.

Requests for reprints should be sent to Gary E. Rosenthal, MD, Program in Health Care Research, Section of General Internal Medicine 111G (W), Cleveland Veterans Affairs Medical Center, 10701 East Blvd, Cleveland, OH 44106.

This paper was accepted June 17, 1996.

TABLE 1—Mean Observed and Predicted Mortality Rates and Standardized Mortality Ratios (SMRs) for the Seven Study Diagnoses in US Hospitals, 1991

Diagnosis (No. Hospitals[a])	No. Patients per Hospital, Mean ± SD	30-Day Mortality Rate, %		
		Observed, Mean ± SD (Range)	Predicted, Mean ± SD (Range)	SMR, Mean ± SD (Range)
Acute myocardial infarction (n = 946)	166 ± 69	19.5 ± 4.5 (5.1–36.9)	20.2 ± 2.2 (13.7–30.9)	0.97 ± 0.21 (0.34–1.80)
Congestive heart failure (n = 1914)	195 ± 86	12.4 ± 3.2 (2.1–25.2)	12.7 ± 0.9 (9.0–16.4)	0.98 ± 0.25 (0.19–1.90)
Pneumonia (n = 1559)	161 ± 56	14.6 ± 4.3 (3.7–43.8)	14.6 ± 1.2 (9.4–19.1)	1.00 ± 0.28 (0.27–3.10)
Obstructive lung disease (n = 199)	130 ± 28	7.4 ± 3.1 (0.9–20.5)	7.4 ± 1.3 (3.7–11.3)	1.01 ± 0.40 (0.13–2.11)
Stroke (n = 1175)	159 ± 56	17.1 ± 3.8 (4.6–36.5)	17.7 ± 1.4 (13.6–23.1)	0.97 ± 0.21 (0.28–1.88)
Coronary bypass surgery (n = 516)	248 ± 149	5.3 ± 2.3 (0.0–15.5)	5.2 ± 0.5 (3.8–7.7)	1.02 ± 0.44 (0.00–3.37)
Hip fracture (n = 628)	140 ± 41	6.3 ± 2.3 (1.0–16.0)	6.1 ± 0.6 (4.3–8.4)	1.02 ± 0.37 (0.16–2.42)

[a]Number of hospitals meeting the study criterion of 100 or more discharges for a particular diagnosis.

TABLE 2—Correlations between Hospital Standardized Mortality Ratios (SMRs) for Individual Pairs of Diagnoses (Pearson Coefficients) and Correlations between SMR Quintiles (Spearman Coefficients)

Diagnosis	Pearson/Spearman Correlation Coefficient (No. Hospitals in Analysis)					
	Congestive Heart Failure	Pneumonia	Stroke	Obstructive Lung Disease	Coronary Bypass Surgery	Hip Fracture
Acute myocardial infarction	.18[a]/.17[a] (936)	.17[a]/.15[a] (832)	.17[a]/.17[a] (826)	.16[b]/.13 (172)	.26[a]/.22[a] (426)	.10[b]/.08 (533)
Congestive heart failure	. . .	.19[a]/.16[a] (1399)	.20[a]/.19[a] (1166)	.34[a]/.34[a] (196)	.09[b]/.04 (495)	.23[a]/.18[a] (608)
Pneumonia		. . .	.19[a]/.21[a] (1039)	.22[c]/.16[b] (188)	.03/.04 (406)	.07/.05 (589)
Stroke			. . .	.09/.12 (185)	.06/.00 (407)	.18[a]/.15[a] (582)
Obstructive lung disease				. . .	.20/.12 (92)	.07/.03 (148)
Coronary bypass surgery					. . .	.07/.04 (276)

[a]Significantly different from zero at $P < .001$.
[b]Significantly different from zero at $P < .05$.
[c]Significantly different from zero at $P < .01$.

TABLE 3—Level of Agreement between Hospital Standardized Mortality Ratio Quintile Rankings for the Seven Study Diagnoses, as Determined by the Weighted Kappa Statistic

Diagnosis	Congestive Heart Failure	Pneumonia	Stroke	Obstructive Lung Disease	Coronary Bypass Surgery	Hip Fracture
Acute myocardial infarction	.12	.09	.11	.07	.16	.04
Congestive heart failure	. . .	.11	.12	.22	.07	.13
Pneumonia		. . .	.13	.08	.03	.04
Stroke			. . .	.08	−.01	.11
Obstructive lung disease				. . .	.08	.01
Coronary bypass surgery					. . .	.04

coefficient; correlations between hospital quintile rankings were determined via the Spearman rank coefficient. Second, the level of agreement between hospital quintiles for pairs of diagnoses was determined with the weighted kappa statistic.[41] Kappa values, which account for the agreement between two observations that is due to chance alone, have a possible range of −1 to 1. A value of 0 indicates agreement that is no better than chance, while negative values denote agreement that is worse than chance. Positive values of 0 to .20 indicate slight agreement, values of .21 to .40 indicate fair agreement, values of .41 to .60 indicate moderate agreement, and values greater than .60 indicate substantial to almost perfect agreement.[42] Third, as a means of further examining agreement, hospitals in the highest and lowest standardized mortality ratio quintiles for congestive heart failure were identified, and quintiles for the other six diagnoses were determined. Congestive heart failure was chosen because it yielded the largest number of pairwise comparisons.

TABLE 4—Quintile Rankings of Hospitals in the Lowest and Highest Congestive Heart Failure Mortality Quintiles with Respect to the Other Six Study Diagnoses

Diagnosis	Congestive Heart Failure Mortality Quintile	No. Hospitals	No. Hospitals (% of Total)				
			Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5
Acute myocardial infarction	Lowest	144	39 (27)	30 (21)	33 (23)	24 (17)	18 (12)
	Highest	188	20 (11)	30 (16)	39 (21)	41 (22)	58 (31)
Pneumonia	Lowest	244	69 (28)	55 (23)	44 (18)	39 (16)	37 (15)
	Highest	275	37 (13)	51 (19)	43 (16)	63 (23)	81 (29)
Stroke	Lowest	201	63 (31)	43 (21)	39 (19)	33 (16)	23 (11)
	Highest	227	30 (13)	39 (17)	48 (21)	53 (23)	57 (25)
Obstructive lung disease	Lowest	29	12 (41)	7 (24)	5 (17)	4 (14)	1 (3)
	Highest	22	0 (0)	4 (18)	4 (18)	5 (23)	9 (41)
Coronary bypass surgery	Lowest	83	19 (23)	16 (19)	17 (20)	17 (20)	14 (17)
	Highest	100	16 (16)	17 (17)	21 (21)	20 (20)	26 (26)
Hip fracture	Lowest	70	25 (36)	16 (23)	12 (17)	8 (11)	9 (13)
	Highest	119	15 (13)	26 (22)	14 (12)	25 (21)	39 (33)

Note. Quintiles are ordered according to increasing standardized mortality ratios (e.g., Quintile 1 includes hospitals with the lowest ratios).

Results

Mean observed 30-day mortality rates for the seven diagnoses ranged from 5.3% for coronary artery bypass surgery to 19.5% for acute myocardial infarction, while mean predicted rates ranged from 5.2% to 20.2% (Table 1). Across individual hospitals, variations in observed and predicted mortality rates were substantial; for example, for acute myocardial infarction, mean observed mortality rates ranged from 5.1% to 36.9%, while mean predicted mortality rates ranged from 13.7% to 30.9%. Considerable variation also existed in standardized mortality ratios. For acute myocardial infarction, ratios ranged from 0.34 to 1.80 (5-fold difference); for congestive heart failure, they ranged from 0.19 to 1.90 (10-fold difference).

Correlations between hospital standardized mortality ratios for the seven diagnoses were relatively weak (Table 2). Although many of the correlation coefficients were statistically significant as a result of the large number of hospitals in the analyses, they ranged from only .03 (pneumonia and coronary artery bypass surgery) to .34 (congestive heart failure and chronic obstructive lung disease). Of the 21 possible correlations, only 6 were .20 or greater, while 7 were less than .10. Results were similar in analyses limited to hospitals with 200 or more patients for individual diagnoses. The resulting correlation coefficients increased somewhat but generally remained modest. Eight of the 21 possible correlations were based on 100 or more hospitals: acute myocardial infarction and congestive heart failure ($r = .28$), acute myocardial infarction and pneumonia ($r = .25$), acute myocardial infarction and stroke ($r = .38$), acute myocardial infarction and coronary bypass surgery ($r = .24$), congestive heart failure and stroke ($r = .22$), congestive heart failure and coronary bypass surgery ($r = .13$), congestive heart failure and pneumonia ($r = .29$), and stroke and pneumonia ($r = .20$).

Correlations between standardized mortality ratio quintiles were also relatively low (Table 2), ranging from .00 to .34. As a means of further characterizing agreement between quintiles, weighted kappa statistics were determined for the 21 pairs of diagnoses (Table 3). Kappa values ranged from −.01 to .22; only one value exceeded .20, the threshold for "fair" agreement.

Finally, hospitals in the lowest and highest standardized mortality ratio quintiles for congestive heart failure were identified to examine the implications of classifying hospitals as "outliers" for a single diagnosis (Table 4). For hospitals in the lowest quintile, the percentage that were also categorized in the lowest quintile with respect to the other six diagnoses ranged from 23% to 41%, while the percentage categorized in the highest quintile ranged from 3% to 17%. For hospitals in the highest quintile for congestive heart failure, the percentage of hospitals that were also categorized in the highest quintile with respect to the other six diagnoses ranged from 25% to 41%, while the percentage of hospitals categorized in the lowest quintile ranged from 0% to 16%.

Discussion

The current study examined relationships between hospital mortality rates for seven common diagnoses. Publicly available data from the 1993 Medicare Hospital Mortality Information Report revealed that correlations between standardized mortality ratios were relatively weak. Correlation coefficients ranged from .03 to .34, indicating that the amount of variance in standardized hospital mortality rates for one diagnosis that could be explained by another diagnosis was no greater than 10% for the 21 possible pairs of diagnoses examined. In addition, when hospital standardized mortality ratios were categorized into quintiles, the level of agreement between most pairs of diagnoses, as measured by the weighted kappa statistic, was only "slight." The findings suggest that mortality rates for different diagnoses may be poorly related and that it may not be valid to judge hospital quality on the basis of a single diagnosis or even a few diagnoses.

Prior studies have examined the validity of mortality data as a measure of hospital quality from several perspectives. First, numerous studies have demonstrated that methods used to standardize mortality rates may underestimate the risk of death in specific types of patients[21–23,26,28,43,44]; the findings question the abil-

ity to make unbiased comparisons across hospitals. A second set of studies has investigated the impact of random variation on hospital mortality rates and has yielded conflicting results. Luft and Romano[27] found that hospital mortality rates in patients undergoing coronary bypass surgery were consistent over time; however, Park et al.[45] found that rates were substantially affected by random variation, leading them to suggest that periods of greater than 1 year be used in comparing hospital mortality rates.

A third set of studies has investigated relationships between standardized mortality rates and other measures of hospital quality and has also yielded conflicting results.[2,20,24,29–31,45] For example, Dubois et al.[20] found that hospitals that had higher standardized mortality rates had higher rates of preventable deaths on the basis of implicit review criteria but not on the basis of explicit criteria. In addition, Kahn et al.[30] found that mortality was higher among patients receiving poorer quality care for four diagnoses (myocardial infarction, heart failure, pneumonia, and stroke) but not for a fifth diagnosis (hip fracture), while Thomas et al.[29] found that hospital mortality was related to quality of care, as measured by a Medicare peer review organization, for only one of three diagnoses. Finally, although Knaus et al.[5] demonstrated a relationship between intensive care mortality rates and organizational aspects of care, the findings were not replicated in a follow-up study.[46]

Few studies have examined the consistency of mortality rates across different diagnoses. In a study using 1984 HCFA data adjusted for age, sex, and race only, Chassin et al.[8] found that correlations between hospital mortality rates for different diagnoses generally ranged from 0 to .3. Using more current HCFA data that were adjusted for other demographic and clinical factors and restricting analyses to hospitals with "larger" sample sizes, the current study provides further evidence that mortality rates for different diagnoses may be only weakly related. Although the variability in mortality rates across diagnoses may reflect differences in hospital quality for different clinical services, the weak associations found in the current study between diagnoses that would be managed by similar practitioners (e.g., congestive heart failure, pneumonia, obstructive lung disease) suggest that hospital mortality data may be strongly influenced by random variation or factors unrelated to quality of care.

In interpreting the findings, two potential limitations should be considered. First, to assess hospital quality, the study used HCFA mortality data, which may imprecisely adjust for severity of illness. Thus, it is possible that correlations between diagnoses would have been higher if the study had used more precise methods of adjusting for differences in severity of illness. However, prior data suggest that hospital rankings based on the HCFA methodology are highly correlated with rankings based on more accurate methods of severity adjustment.[37] Moreover, in spite of their limitations, the HCFA data and other similar methods are widely used to profile hospital performance.[1,7,14–17,34–36]

Second, the weak associations may reflect the use of single-year mortality data and/or inadequate sample sizes. However, even when analyses were restricted to hospitals with 200 or more patients, correlations remained relatively weak (.13 to .38). Moreover, no current initiatives to profile hospital performance have set such rigid sample size criteria.

The current findings have important implications for the design of initiatives to profile hospital quality and the use of mortality data by purchasers. The findings suggest that profiling hospital mortality on the basis of a single diagnosis, as is commonly done,[1,2,19] may be problematic. Thus, efforts to profile hospital quality should consider evaluating multiple diagnoses and/or examining data over multiple years. Moreover, in the absence of other, more direct measures of hospital quality, regulatory agencies and purchasers should exhibit caution when interpreting hospital mortality based on a limited set of diagnoses. □

Acknowledgments

This work was supported by the National Institute on Aging's Claude D. Pepper Older Americans Independence Center (grant AG10418-01) and by a Picker/Commonwealth Scholar's Award from the Commonwealth Fund to Gary E. Rosenthal.

References

1. *Annual Report of the California Hospital Outcomes Project December 1993, Volume One: Study Overview and Results Summary.* Sacramento, Calif: Office of Statewide Hospital Planning and Development; 1993.
2. Hannan EL, Kilburn H, O'Donnell JF, Lukacik G, Shields EP. Adult open heart surgery in New York state. *JAMA.* 1990; 264:2768–2774.
3. *Hospital Effectiveness Report.* Harrisburg, Pa: Pennsylvania Health Care Containment Council; 1991.
4. *Iowa Hospital Resource and Outcome Report, July 1990 through June 1991, DRG Specific Version.* Des Moines, Iowa: Iowa Health Data Commission; 1992.
5. Knaus WA, Draper EA, Wagner DP, Zimmerman JE. An evaluation of outcome from intensive care in major medical centers. *Ann Intern Med.* 1986;104:410–418.
6. Mazzolini J. Report grades Cleveland hospitals. *Cleveland Plain Dealer.* April 29, 1993:1A.
7. Sullivan LW, Toby W. *Medicare Hospital Information Report 1988, 1989, 1990: Volumes 1–55.* Washington, DC: Health Care Financing Administration, US Dept of Health and Human Services; 1992.
8. Chassin MR, Park RE, Lohr KN, Kessey J, Brook RH. Differences among hospitals in Medicare patient mortality. *Health Serv Res.* 1989;24:1–31.
9. Williams SV, Nash DB, Goldfarb N. Differences in mortality from coronary artery bypass graft surgery at five teaching hospitals. *JAMA.* 1991;266:810–815.
10. Belk HD, Harris JS, Wood LW. A strategy for employer health care value management. *J Occup Med.* 1991;33:376–380.
11. Iglehart JK. Competition and the pursuit of quality: a conversation with Walter McClure. *Health Aff.* 1988;7:79–80.
12. Shaller DV, Woods P. Reforming the market for value in health care: the Cleveland experience. *J Occup Med.* 1991; 33:358–362.
13. Miller D. Memphis business group on health: a model for health care reform and cost containment. *Managed Care Q.* 1994; 2:1–5.
14. Winslow R. Cincinnati firms cutting costs with hospital-ranking system. *Wall Street Journal.* April 2, 1993:B1.
15. Jensen J. Consumers see mortality data as a useful tool. *Modern Healthcare.* 1992; 22(25):82.
16. Gross PA, Schaffer WA. Consumer awareness of hospital mortality data. *J Health Care Market.* 1989;9(4):52–55.
17. Rubin R. America's best hospitals. *US News and World Report.* July 18, 1994: 54–65.
18. Rosenthal GE, Harper DL. Cleveland Health Quality Choice: a model for community-based outcomes assessment. *Jt Comm J Quality Improvement.* 1994;20:425–443.
19. Localio AR, Hamory BH, Sharp TJ, Weaver SL, TenHave TR, Landis JR. Comparing mortality in adult patients with pneumonia: a case study of statistical methods in a managed care program. *Ann Intern Med.* 1995;122:125–132.
20. Dubois RW, Rogers WH, Moxley JH III, Draper D, Brook RH. Hospital inpatient mortality: is it a predictor of quality? *N Engl J Med.* 1987;317:1674–1680.
21. Green J, Passman LJ, Wintfeld N. Analyzing hospital mortality: the consequences of diversity in patient mix. *JAMA.* 1991;265: 1849–1853.
22. Green J, Wintfeld N, Sharkey P, Passman LJ. The importance of severity of illness in assessing hospital mortality. *JAMA.* 1990; 263:241–246.
23. Greenfield S, Aronow HU, Elashoff RM, Watanabe D. Flaws in mortality data: the

hazards of ignoring comorbid disease. *JAMA.* 1988;260:2253–2255.
24. Hartz AJ, Gottlieb MS, Kuhn EM, Rimm AA. The relationship between adjusted hospital mortality and the results of peer review. *Health Serv Res.* 1993;27:765–777.
25. Kahn KL, Brook RH, Draper D. Interpreting hospital mortality data: how can we proceed? *JAMA.* 1988;260:3625–3628.
26. Rosenthal GE. Potential for bias in severity-adjusted hospital outcomes data: an analysis of patients with rheumatic disease. *J Rheumatol.* 1994;21:721–727.
27. Luft HS, Romano PS. Chance, continuity, and change in hospital mortality rates: coronary artery bypass graft patients in California hospitals, 1983 to 1989. *JAMA.* 1993;270:331–337.
28. Blumberg MS. Biased estimates of acute myocardial infarction mortality using MedisGroups admission severity groups. *JAMA.* 1991;265:2965–2970.
29. Thomas JW, Holloway JJ, Guire KE. Validating risk-adjusted mortality as an indicator for quality of care. *Inquiry.* 1993;30:6–22.
30. Kahn KL, Rogers WH, Rubenstein LV, et al. Measuring quality of care with explicit process criteria before and after implementation of the DRG-based prospective payment system. *JAMA.* 1990;264:1969–1973.
31. Rubenstein LV, Kahn KL, Reinisch EJ, et al. Changes in quality of care for five diseases measured by implicit review, 1981 to 1986. *JAMA.* 1990;264:1974–1979.
32. Berwick DM, Wald DL. Hospital leaders' opinions of the HCFA mortality data. *JAMA.* 1990;263:247–249.
33. Blumberg MS. Comments on HCFA hospital death rate statistical outliers. *Health Serv Res.* 1987;21:715–739.
34. Iezzoni LI. Measuring the severity of illness and case mix. In: Goldfield N, Nash DB, eds. *Providing Quality Care: The Challenge to Clinicians.* Philadelphia, Pa: American College of Physicians; 1989.
35. Iezzoni LI, Daley J. A description and clinical assessment of the Computerized Severity Index. *QRB Qual Rev Bull.* 1992;18:44–52.
36. Young WW, Kohler S, Kowalski J. PMC Patient Severity Scale: derivation and validation. *Health Serv Res.* 1994;29:367–390.
37. Krakauer HK, Bailey RC, Skellan KJ, et al. Evaluation of the HCFA model for the analysis of mortality following hospitalization. *Health Serv Res.* 1992;27:317–335.
38. *Technical Supplement: Medicare Hospital Information for FY91.* Washington, DC: Health Care Financing Administration, US Dept of Health and Human Services; 1993.
39. Daley J, Jencks S, Draper D, Lenhart G, Thomas N, Walker J. Predicting hospital associated mortality for Medicare patients: a method for patients with stroke, pneumonia, acute myocardial infarction, and congestive heart failure. *JAMA.* 1988;260:3617–3624.
40. Mushlin AI, Black ER, Connolly CA, Buonaccorso KM, Eberly SW. The necessary length of hospital stay for chronic pulmonary disease. *JAMA.* 1991;266:80–83.
41. Kramer MS, Feinstein AR. Clinical biostatistics: LIV. The biostatistics of concordance. *Clin Pharmacol Ther.* 1981;29:111–123.
42. Landis RJ, Koch GG. The measurement of observer agreement for categorical data. *Biometrics.* 1977;33:159–174.
43. Escarce JJ, Kelley MA. Admission source to the medical intensive care unit predicts hospital death independent of APACHE II score. *JAMA.* 1990;264:2389–2394.
44. Gordon HS, Rosenthal GE. Risk adjusted outcomes in transfer patients: potential for bias in assessing hospital performance. *J Gen Intern Med.* 1994;9(suppl 2):53.
45. Park RE, Brook RH, Kosecoff J, et al. Explaining variations in hospital death rates: randomness, severity of illness, quality of care. *JAMA.* 1990;264:484–490.
46. Zimmerman JE, Shortell SM, Rousseau DM, et al. Improving intensive care: observations based on organizational case studies in nine intensive care units: a prospective study. *Crit Care Med.* 1993;21:1443–1451.